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Effect Of Simulated Hail Damage On Barley

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E. L. Deckard and J. J. Hammond

A simulated hail study on barley was initiated in 1971 to obtain research data that are an estimation of the effect of hail damage (stem bending) on grain yield and other agronomic characteristics of two varieties in North Dakota. Loss factors to be used by hail adjustors to estimate hail damage to barley at various stages of growth were developed from the data. The loss factors used by hail adjustors on small grains in North Dakota prior to the completion of this study were developed mostly from data on simulated hail damage to winter wheat in Oklahoma (5). These factors were considered not accurate to predict hail damage losses on barley in North Dakota since the data were on a different crop in a different cropping area. A recent study on spring wheat in North Dakota (1) indicated that some changes in the small grain loss factors were necessary for spring wheat. Accurate loss factors would allow for fair adjustment procedures and would benefit both the North Dakota farmers and the insurance industry.

A study partially funded by the National Crop Insurance Association (NCIA) and the Crop Insurance Research Bureau (CIRB) and conducted by the North Dakota State University Agricultural Experiment Stations at Fargo, Carrington, and Minot. Dr. Deckard and Dr. Hammond are associate professors, Dept. of Agronomy. The authors thank R. H. Busch, B. Hoag, H. Olson, and G. E. McIntyre for their assistance. G. A. Peterson, former professor of agronomy, NDSU, also is acknowledged with gratitude for helpful advice and assistance in experimentation.

PROCEDURES

Identical experiments were located at the North Dakota Agricultural Experiment Station at Fargo, the Carrington Branch Experiment Station, and the North Central Experiment Station at Minot. These three locations were chosen to represent the major barley production areas of North Dakota. Fargo is on the extreme eastern edge of North Dakota, Carrington is approximately 100 miles west and 50 miles north of Fargo, and Minot is approximately 130 miles northwest of Carrington (Fig. 1). Fargo and Carrington are located in Zone 1, and Minot is located on the eastern edge of Zone 2 according to the NCIA small grain loss chart.

Dickson and Conquest barley were used in this study and were recommended varieties for malting and feed purposes when this study was initiated. Dickson was chosen because it was grown on 42% of the barley acreage in North Dakota in 1971. Conquest was chosen as a barley "type" that drops 2 to 3% of its spikes prior to harvest. Conquest was grown on only 10% of the barley acreage in 1971, but future varieties could be of the Conquest "type."

Each plot of all experiments consisted of four rows 30cm apart and 2.4m long. All plots were separated by two rows of winter wheat which remains vegetative after spring planting

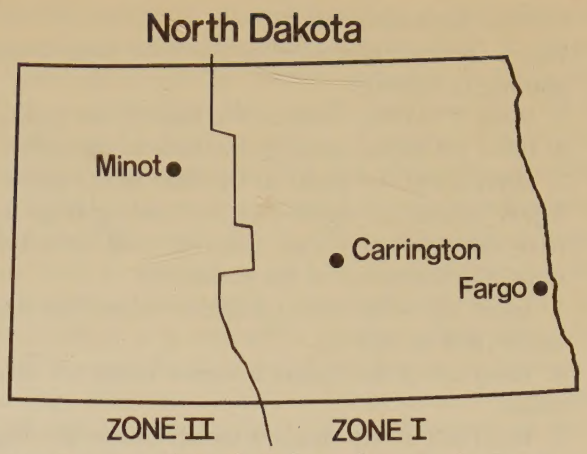

Figure 1. Diagram of North Dakota showing the locations of the simulated hail studies in relation to the NCIA Zones.

in North Dakota. Each variety was planted as separate but adjacent experiments. The experimental design was a randomized complete block with four replications.

Treatments. The injury treatments were applied at three growth stages (boot, heading, and soft dough) with the plants considered in a specific stage of growth when 50% of the plants had entered or passed through that stage. The intervals between the boot and heading stages and between the heading and soft dough stages were approximately seven days each. The treatments were applied to each row of the plot, and all treated stems of north-south rows were bent eastward. The control (no treatment) and stem bending treatments are listed below, and illustrated in Figure 2.

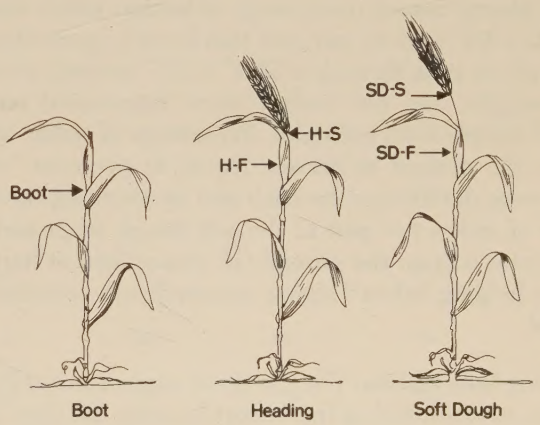

Figure 2. Barley plant at three stages of growth showing the five stem bending treatments.

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A. Control (no treatment).
B. Injury treatments applied at the boot stage (awns beginning to appear):
   1. bend 1/3 of the stems at the base of the spike,
   2. bend 2/3 of the stems at the base of the spike,
   3. bend 3/3 of the stems at the base of the spike.
C. Injury treatments applied at the heading stage (spikes have emerged completely from the boot) or soft dough stage (full extension of the peduncle):
   1. bend 1/3 of the stems 2 inches below the flag leaf collar (H-F or SD-F),
   2. bend 2/3 of the stems 2 inches below the flag leaf collar,
   3. bend 3/3 of the stems 2 inches below the flag leaf collar,
   4. bend 1/3 of the stems at the base of the spike (H-S or SD-S),
   5. bend 2/3 of the stems at the base of the spike,
   6. bend 3/3 of the stems at the base of the spike.

Conquest generally entered a growth stage approximately 1 to 2 days prior to Dickson. Therefore, the two varieties were treated on separate days.

The 1/3 intensity treatment was applied by bending one culm and skipping two, bending one and skipping two, etc. The 2/3 intensity treatment was applied by bending two culms and skipping one, bending two culms and skipping one, etc. Therefore, the treated culms were distributed uniformly throughout the plot.

Data collected. All four rows of each plot were harvested with a plot combine, leaving a four-inch stubble. Grain yield, per cent plump kernels (percentage of kernels which remain on a 6/64" x 3/4" screen), per cent thin kernels (percentage of kernels which pass through a 5/64" x 3/4" screen), average kernel weight, and test weight were determined on the threshed sample from each plot. Percentage of spikes which were on the ground at harvest (equal to per cent "stove pipes") were determined for each plot by counting the total number of spikes per plot at the soft dough stage and the number of spikes on the ground (12 square feet) at harvest. Per cent lodging (when lodging occurred) was recorded for each plot.

Missing Information. The Conquest experiment at Fargo in 1972 is not included in this report because the data were influenced by severe bird damage. The Dickson and the Conquest studies at Fargo in 1972 were sprayed four times during the grain filling period with a bird repellant, Arasan 42S. No other experiments were sprayed with a bird repellant. The bird repellant prevented bird damage to Dickson, but not to Conquest. Although all treatments were applied to Conquest and all plots harvested, the Conquest data are not indicative of simulated hail damage and, therefore, are not presented.

The Carrington study in 1972 was damaged severely by hail on July 2, 1972, when plants were in the late boot to early heading stage. The hail storm resulted in an estimated yield reduction of 60%. Although all treatments were applied at Carrington, the plots were not harvested.

The 1971 and 1972 Minot studies also were damaged by hail (estimated 6 to 8% yield reduction). The hail damage occurred during the late boot to early heading stage in 1971 and one week before harvest in 1972. However, the results from these two studies were considered valid since the hail damage was uniform over all plots and relatively light. Therefore, data from 15 of the 18 experiments initiated are presented in this final report.

Statistical Procedures. Appropriate analyses of variances to test treatments, varieties, years, locations, and the interactions were conducted as outlined for the analyses of a series of experiments in Cochran and Cox (2).

Growing Conditions. All studies were seeded in late April or early May in 1971. Growing conditions were good at all three experimental sites, except for light hail damage at Minot.

Growing conditions at the Minot locations again were very good in 1972 except for the light hail damage. Excessive rainfall in April and May delayed seeding at the Fargo location in 1972. However, the average amount of July precipitation and relatively low July temperatures resulted in near normal grain yields.

Adequate rainfall, near normal temperatures, and early seeding resulted in excellent grain yields at Fargo and Minot in 1973. An extremely dry summer at Carrington in 1973 resulted in low grain yields, especially for Dickson. However, uniform stands were obtained, so the data should give an indication of simulated hail damage effects during a dry year. The grain yields of the control plots from all reported studies are shown in Table 1.

Table 1. Grain yield of control plots of two barley varieties at the Fargo, Carrington, and Minot locations during 1971, 1972, and 1973.

Location	Grain yield of control plots			
	1971	1972	1973	Average
	(bu/A)			
	DICKSON			
Fargo	93.0	96.7	120.7	103.5
Carrington	76.4	‡	34.7	55.6
Minot	55.9§	75.9§	89.3	73.7
	CONQUEST			
Fargo	68.1	†	116.0	92.1
Carrington	79.3	‡	52.9	66.1
Minot	50.3§	67.0§	101.8	73.0

†Yield not presented because of severe bird damage.
‡Experiment not harvested due to severe hail damage.
§Yield not adjusted for light hail damage.

RESULTS

Stem Bending Effects on Grain Yield

Statistical Analyses

A partial analysis of variance for grain yield of treated plots (combined over years) is shown in Table 2. The heading and soft dough treatments were not significantly different in any of the six experiments. The below spike bends always resulted in greater yield losses than the below flag bends. Significant linear trends (straight lines) across bending intensities were obtained for the below spike bends at the heading and soft dough stages for all studies. Significant linear trends for all treatments were obtained for Dickson at Fargo only. The absence of a significant linear trend (slope different from zero) does not indicate necessarily that the specific treatment did not reduce grain yields, but that the yield reduction was not great enough to be significant at the 5 or 1% significance level. All treatments almost always decreased grain yields below the control. There were no significant quadratic trends (curved lines).

A partial analysis of variance for grain yield showing the treatment x year interaction is presented in Table 3. A significant treatment x year interaction indicates that the yield reduction resulting from the specific treatment was not the same each year. A larger number of significant interations was expected than obtained. The lack of significant interactions is desirable, as more accurate hail damage adjustments can be made if the same effect could be expected each year. The year-to-year variation in the environment is responsible for the significant interactions obtained, but with the data collected to date, it is impossible to use weather information to greatly increase the accuracy of hail damage estimates. No relationships between rainfall or temperature data (before, at, or after the treatment date) and yield reductions due to simulated hail damage were observed in this study. A combination of all environmental factors (rainfall, temperature, wind, light, etc.) probably is important in modifying the effect of stem bending. Since only a few treatment x year comparisons were significant and since the data averaged over years would be the best estimate of yield reduction for any one year, only the two- or three-year averages will be presented in this report.

Table 2. Partial analysis of variance of stem bendingeffects on grain yield of two barley varieties at Fargo, Carrington, and Minot, 1971-1973.

	Fargo		Carrington		Minot	
	Conquest†	Dickson	Conquest†	Dickson†	Conquest	Dickson
Treatments	**	**	**	**	**	**
Control vs. others	**	**	**	**	**	**
Boot vs. heading and soft dough	**	**	**	ns	ns	*
Heading vs. soft dough (A)	ns	ns	ns	ns	ns	ns
Spike vs. flag (B)	**	**	**	*	**	**
(A) X (B)	*	ns	ns	ns	ns	ns
Boot linear	ns	*	ns	*	ns	ns
Heading Spike linear	**	**	**	**	**	**
Heading flag linear	ns	**	ns	ns	ns	ns
Soft dough spike linear	**	**	**	*	*	**
Soft dough flag linear	ns	**	ns	ns	ns	ns

*Significant at the 5% level. This effect would be expected 1 time out of 20 as a result of chance.
**Significant at the 1% level. This effect would be expected 1 time out of 100 as a result of chance.
†Two year's data only.

Linear Trends and b Values

The average grain yield data for Dickson at Fargo are presented in Figure 3. Since linear trends were noted (Table 2), the best fitting straight lines (linear regression lines) were developed to depict the effect of stem bending on barley yields. The five regression lines developed for Dickson at Fargo are presented in Figure 4. The slopes of these linear regression lines are called **b** values, and are expressed here as per cent yield reduction for each percentage of stems bent. For example, if we examine the regression line depicting the effect of bending below the spike at the heading stage (H-S treatment), we note that bending 100% of the stems resulted in a 32% yield reduction. Since the regression line is linear, the **b** value is calculated to be 0.32% yield reduction for each percentage of stems bent. If the **b** value is multiplied times the percentage of stems bent, the per cent yield reduction as a result of the stem bending is determined. For example, if stem counts indicate that 40% of the stems were bent at the base of the spike, the estimated yield reduction would be 12.8% (40 x 0.32).

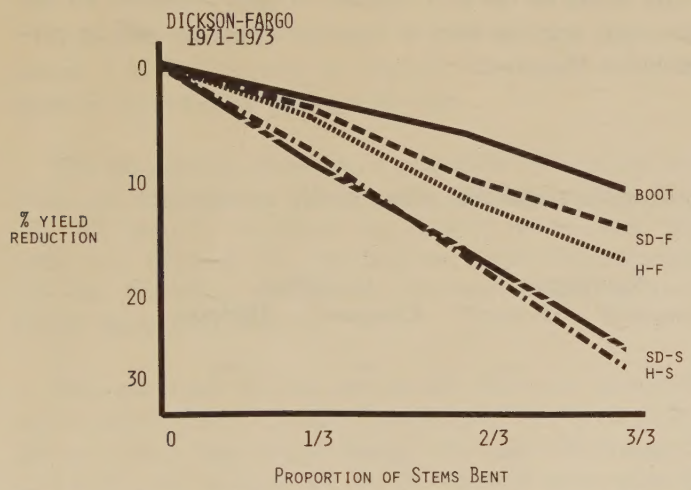

Figure 3. Grain yield of Dickson barley at Fargo as affected by five stem bending treatments, 1971-73. See the Procedures section for a complete description of the five treatments.

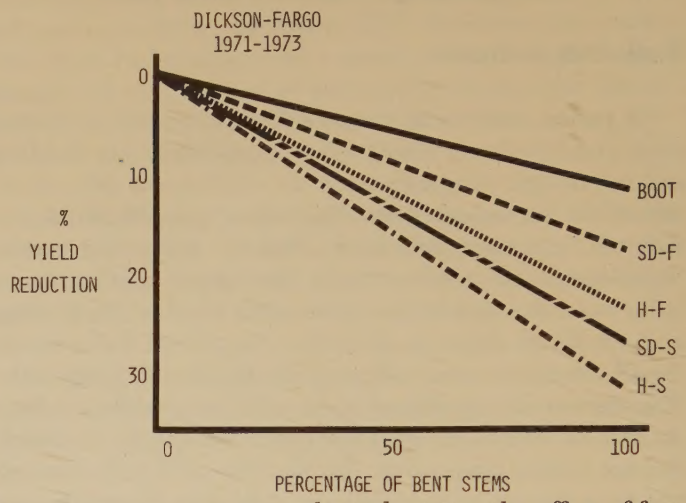

Figure 4. Linear regression lines depicting the effect of five stem bending treatments on grain yields of Dickson barley at Fargo, 1971-73. See the Procedures section for a complete description of the five treatments.

Varietal Comparisons

The **b** values calculated from the regression lines developed for each variety at each location are presented in Table 4. All treatments resulted in yield reductions with the exception of the below flag bends to Conquest at the soft dough stage at Fargo. The negative **b** value (−.04) resulting from this treatment represents a small increase in grain yield, and may be due to chance or a reduction of dropped spikes due to treatment.

A partial analysis of variance for grain yield showing the treatment x variety interactions is presented in Table 5. A significant treatment x variety interaction indicates that the two varieties responded differently to the specific treatment.

Table 3. Partial analysis of variance of stem bending effects on grain yield of two barley varieties at Fargo, Carrington, and Minot, 1971-1973.

	Fargo		Carrington		Minot	
	Conquest†	Dickson	Conquest†	Dickson†	Conquest	Dickson
Treatment x years	*	**	ns	ns	**	**
Boot linear	ns	ns	ns	ns	ns	ns
Heading spike linear	*	ns	ns	ns	**	**
Heading flag linear	ns	ns	ns	ns	ns	ns
Soft dough spike linear	ns	*	ns	ns	**	ns
Soft dough flag linear	ns	ns	ns	ns	**	ns

†Two years' data only.
*,**Significant at the 5% and 1% level respectively.

Again, a larger number of significant interactions was expected than obtained. The lack of significant interactions is desirable and should make hail damage assessments easier and more precise.

Several barley varieties besides Dickson and Conquest are grown in North Dakota. Obtaining simulated hail data on all varieties would be very difficult, especially since varieties are always changing. New varieties generally differ from the predominantly grown varieties by only one or two characters. Therefore, since there were only two significant treatment x variety interactions and since Dickson and Conquest represent two different variety types, the data collected in this study should be applicable to the present and future six-row barley varieties grown in North Dakota.

Table 4. Per cent yield reduction for each percentage of stems bent (b values) as calculated from the regression lines depicting the effect of stem bending on grain yields of two barley varieties grown at Fargo, Carrington, and Minot, 1971-1973.

Treatment	Variety	Location of trial† Fargo	Carrington	Minot
Boot	Conquest	08	.05	.14
Boot	Dickson	.12	.17	.18
Heading-spike	Conquest	.36	.31	.34
Heading-spike	Dickson	.32	.25	.44
Heading-flag	Conquest	.12	.07	.16
Heading-flag	Dickson	.24	.08	.18
Soft dough-spike	Conquest	.51	.41	.27
Soft dough-spike	Dickson	.27	.12	.34
Soft dough-flag	Conquest	−.04	.04	.15
Soft dough-flag	Dickson	.18	.01	.13

†Three years and two years of data for Dickson and Conquest, respectively, at Fargo; two years data for both varieties at Carrington; and three years data for both varieties at Minot.

Location Comparisons

Fargo and Minot exhibited similar **b** values for all five treatments (Table 6). Carrington exhibited similar **b** values compared to Fargo and Minot for the boot, heading-spike, and soft dough-spike treatments, but slightly smaller **b** values for the heading-flag and soft dough-flag treatments. As previously indicated, 1973 was very dry at Carrington whereas 1971 was nearly normal. The lower values shown for Carrington in Table 6 probably are not a result of the very dry year in 1973 as the **b** values were similar for both years. Since three-year data for both varieties at each location were not available, analysis of all data for location differences was not possible. However, using the 1971 and 1973 data only (the two years when all data were obtained), all treatments exhibited non-significant location differences. Therefore, these data do not support the use of zones in North Dakota for adjusting hail damage to barley.

Table 5. Partial analysis of variance of stem bending effects on grain yield of two barley varieties at Fargo, Carrington, and Minot, 1971-1973.

	Fargo†	Carrington	Minot
Treatment X varieties			
Boot linear	ns	ns	ns
Heading spike-linear	ns	ns	ns
Heading flag-linear	ns	ns	ns
Soft dough-spike linear	ns	**	ns
Soft dough-flag linear	*	ns	ns

†Analysis included 1971 and 1973 data only.

*,**Significant at the 5% and 1% level, respectively.

Estimated Leaf Area Reductions

Since the data indicate that the same loss factors can be used throughout North Dakota, **b** values were calculated from the regression lines developed from the mean of the two varieties and the three locations. These values are presented in Table 7 and represent the factors that could be used to estimate yield loss resulting from bent stems. However, bent stems are not the only effect of hail storms. Other effects are leaf damage and seed shattering. A hail adjustor can estimate seed shattering by counting the percentage of missing kernels, and these lost kernels would be a direct loss of grain yield. However, neither the extent of leaf damage nor the effect of leaf damage on grain yield is estimated so easily.

Research to determine the effect of leaf area reduction on grain yield of barley is not available. However, using other methods (radioactive carbon and carbon dioxide exchange), the relative contribution of the various plant parts to grain production has been estimated. Approximately 20% of the mature barley grain dry weight is thought to be produced by the plant (predominantly by the leaves) before flowering, stored in the leaves and stems, and translocated to the grain during the grain filling period (8). The remaining 80% of the grain dry weight is produced by the plant after flowering and then translocated to the grain. Other studies indicate that the leaves are responsible for approximately 45% of the dry mat-

Table 6. Mean per cent yield reduction for each percentage of stems bent as calculated from the regression lines depicting the effect of stem bending on grain yields at Fargo, Carrington, and Minot, 1971-1973.

Treatment	Location of Trial† Fargo	Carrington	Minot
Boot	.11	.10	.16
Heading-spike	.33	.28	.39
Heading-flag	.20	.07	.17
Soft dough-spike	.36	.28	.30
Soft dough-flag	.10	.03	.14
Average	.22	.15	.23

†Three years and two years of data for Dickson and Conquest, respectively, at Fargo; two years of data for both varieties at Carrington; and three years of data for both varieties at Minot.

ter produced by the barley plant after flowering (6, 7, 8). The stem and spike would account for the remaining 55% of the dry matter production after flowering.

Using these average percentages quoted in the literature, the **b** value for the regression line depicting the effect of leaf area reductions at the boot stage on grain yields could be calculated, if we make the following assumptions:

1. A reduction in leaf area of 40 per cent would occur if a hail storm was severe enough to hit every stem once; and
2. The regression of leaf area reduction on grain yield is linear.

The first assumption cannot be supported by experimental data. The second assumption is supported somewhat by experimental data which shows the percentage of light intercepted to be positively correlated, within limits, with net photosynthesis and dry matter production (3, 4). The calculated **b** values are presented in Table 7. The value of 0.14 per cent yield reduction for each percentage of stems bent at the boot stage was calculated by the following formula:

0.14 = (80% of total) x (45% contribution of leaves) x (40% leaf area reduction).

The **b** value at the boot stage would be higher than at later stages since the reduced leaf area would hold throughout the grain filling period. The leaves would become less important as the plant approached maturity. The estimated **b** values for the heading and soft dough stages are 0.11 and 0.08, respectively.

These estimates of the leaf area factors appear realistic. Since the factors represent the per cent yield reduction due to leaf damage for each percentage of stems bent, they can be added to the stem bending factors to arrive at the loss factors to be used for adjusting hail damage (stem bending factors weighted for leaf damage).

Recommended Loss Factors versus "Small Grain" Loss Factors

These recommended loss factors are compared in Table 8 with the factors used by NCIA for small grains in North Dakota during this study. Losses before the heading stage are deferred until after heading with the "small grain" factors so a comparison with the boot stage treatments cannot be made. Barley blooms in the boot stage while other small grains bloom in the heading stage, so the growth stages of barley, relative to kernel development, do not correspond with those of the other small grains. Therefore, the "small grain" milk stage factors are compared to the new heading stage factors, as the kernels approximated the early milk stage when heading treatments were applied. A direct comparison could be made at the soft dough stage.

The recommended above flag leaf factors at either the heading or soft dough stages of barley are slightly higher than the "small grain" factors for Zone 1 and markedly lower than those in Zone 2. The recommended below flag treatments at either the heading or soft dough stages of barley are similar to small grain factors for both Zone 1 and Zone 2.

Table 7. Factors (b values) depicting the effect of stem bending on grain yields of barley (average of two varieties grown at three locations, 1971-1973), and estimated factors depicting the effect of leaf area reductions on grain yield.

Treatment	Effect of stem bending†	Effect of leaf area reductions‡	Grain yield loss factors§
Boot	.12	.14	.26
Heading-spike	.34	.11	.45
Heading-flag	.16	.11	.27
Soft dough-spike	.32	.08	.40
Soft dough-flag	.10	.08	.18

†Per cent yield reduction for each percentage of stems bent.

‡Estimated per cent yield reduction from the reduced leaf area resulting from hail bending one per cent of the stems (assuming linear trends through 100% of bent stems).

§Stem bending factors weighted for leaf area reductions (calculated by adding the stem bending factors and leaf area reduction factors).

Comparisons of Barley and Wheat Results

A comparison of the simulated hail damage (stem bending) effects on barley and Waldron wheat (1) would indicate that common loss factors cannot be used for all small grains (Table 9). Due to the different growth stage sequence of these two crops, the milk stage factors for wheat must be compared with the heading stage factors for barley. Obviously, the same factors cannot be used for both crops as the **b** values for Waldron wheat are approximately twice as large as those for barley at both Fargo and Carrington.

Table 8. Comparison between the loss factors calculated from simulated hail study data (weighted for leaf damage) and the present loss factors used in Zones 1 and 2 of North Dakota.

Treatment	Recommended loss factors†	Present loss factors‡ Zone 1	Zone 2
Boot	.26	—	—
Heading-spike	.45	.40	.70
Heading-flag	.27	.30	.30
Soft dough-spike	.40	.30	.60
Soft dough-flag	.18	.20	.20

†Per cent yield reduction for each percentage of bent stems as calculated from simulated hail study data (weighted for leaf damage).

‡Loss factors used for small grains in North Dakota during this study; the presently used milk stage factors are compared to the new heading stage factors as kernels approximated the early milk stage when heading treatments were applied.

Stem Bending Effects on Yield Components

The stem bending reduced grain yields by affecting dropped spikes, kernel weight, and kernels per spike (Table 10). The effect on dropped spikes and kernel weight was determined, and the effect on kernels per spike was calculated from the formula: (1−**b** yield) = (1−**b** dropped spikes) (1−**b** kernel weight) (1−**b** kernels/spike), where **b** is the slope of the regression line depicting the effect of stem bending on each of the characters.

Table 9. Comparison of stem bending effects on grain yields of barley and Waldron wheat at Fargo and Carrington.

Treatment	Fargo		Carrington	
	Barley	Wheat§	Barley	Wheat§
	(% yield reduction/each percentage of stems bent)			
Boot	.11	.39	.10	.29
Heading-spike	.33	.61	.28	.67
Heading-flag	.20	.39	.07	.45
Soft dough-spike	.36	.51	.28	.52
Soft dough-flag	.10	.16	.03	.30

§Data of R. H. Busch (1) showing effects of bending stems of Waldron wheat.

Bending stems at the boot stage resulted in a .12% yield reduction for each percentage of stems bent (Table 7). This yield reduction was the result of small but similar effects on dropped spikes, kernel weight, and kernels per spike. The yield reduction caused by the heading-spike treatment (**b** value of .34) was the result of relatively large but similar effects on the three factors. The heading-flag treatment caused yield reductions (**b** value of .16) by affecting kernel weight and kernels per spike but not dropped spikes. Compared to the heading stage treatments, the soft dough stage treatments resulted in similar grain yield reductions by having a similar effect on dropped spikes, a larger effect on kernel weight, and a smaller effect on kernels per spike. At the soft dough stage, the total number of kernels per spike is determined and reducing the flow of assimilates to the grain would cause a reduction in kernel weight. At the heading stage, reducing the flow of assimilates to the spike results in the development of fewer kernels. Therefore, the reduced amount of assimilates is divided among a reduced number of kernels, and kernel weight is less affected.

The **b** values, which represent the yield loss as a result of stem bending, include losses as a result of dropped spikes, reduced kernel weight, and reduced number of kernels per spike. Therefore, hail adjustments for these three factors (dropped spikes, kernel weight, and kernels per spike) are not necessary if the **b** value for yield losses is used in the adjustment.

Stem Bending Effects on Barley Quality

In addition to reducing grain yields, all stem bending treatments reduced the quality of the harvested grains as measured by test weight, per cent plump kernels, and per cent thin kernels (Table 11). Similar results were obtained for both varieties and at the three locations.

The boot treatments resulted in the least reduction in test weight and per cent plump kernels and the least increase in per cent thin kernels among the five treatments. The below spike treatments resulted in greater quality reductions than the below flag treatments. Also, the soft dough treatments resulted in greater quality reductions than the heading treatments.

Table 10. Mean dropped heads, kernel weight, and number of kernels per spike as related to yield reductions resulting from the stem bending treatments applied to two barley varieties at three locations, 1971-1973.

Treatment	b values			
	Reduction† in grain yield	Increase† in dropped spikes	Reduction† in kernel weight	Reduction‡ in kernels per spike
Boot	.12	.03	.03	.06
Heading-spike	.34	.15	.12	.12
Heading-flag	.16	.01	.06	.10
Soft dough-spike	.32	.13	.17	.06
Soft dough-flag	.10	.02	.09	.00

†Per cent increase in dropped spikes and per cent decrease in grain yield and kernel weight for each percentage of stems bent as calculated from the regression lines depicting the effect of stem bending on these three characters.
‡**b**values as estimated from the equation:
(1−**b** yield) = (1−**b** dropped head) (1−**b** kernel weight) (1−**b** kernel/spike)

A **b** value of .05 for test weight as noted for the below spike bends at the soft dough stage indicates that if 100 per cent of the stems were bent, the test weight would be reduced by 5 lb/bu (.05 x 100). The same 100 per cent treatment would cause a decrease in per cent plump kernels of 35 percentage points and an increase in per cent thin kernels of 11 percentage points. This effect would be independent of the check or untreated plot. That is, if the check was 2 per cent thins, the treated plot would be 13 per cent thins; if the check was 20 per cent thins, the treated plot would be 31 per cent thins; etc.

These **b** values would represent the loss in quality due to bent stems. Leaf damage would cause an additional decrease in crop quality. Barley which grades "Malting Barley" may have a maximum of 15% thin kernels and a minimum test weight of 43 lb/bu. Therefore, the stem bending and leaf damage as a result of a hail storm could easily change a crop from "Malting Barley" to nonmalting or "feed" barley.

Table 11. Effects of stem bending on test weight, per cent plump kernels, and per cent thin kernels of two barley varieties at three locations, 1971-1973.

Treatment	b values† Test weight	% plump kernels	% thin kernels
Boot	.01	.04	.01
Heading-spike	.03	.21	.06
Heading-flag	.02	.15	.04
Soft dough-spike	.05	.35	.11
Soft dough-flag	.02	.24	.06

†Decrease in test weight (lb/bu) and per cent plump kernels and increase in per cent thin kernels for each percentage of stems bent as calculated from the regression lines depicting the effect of stem bending on these three characteristics.

SUMMARY

Yield loss factors for barley were developed to estimate the stem injury portion of hail damage. The stem injury effects on barley yields can be predicted accurately in North Dakota, since similar factors were obtained each year and at each location for both Conquest and Dickson.

Factors for leaf damage were estimated and added to the factors for stem damage to obtain yield loss factors that could be used by hail adjustors to estimate hail damage. The loss factors developed from this study for above flag leaf stem damage are different from the "small grain" loss factors used by adjustors on barley prior to and during this study. The loss factors for below flag leaf stem damage were similar to the "small grain" loss factors.

The "small grain" loss charts divided the state into two zones. The data from this study would indicate that the two zones are not different and are unnecessary. Also, the loss factors developed for barley are considerably smaller than the loss factors recently developed for Waldron wheat in North Dakota.

All stem bending treatments reduced the quality of the harvested grain as measured by test weight, per cent plump kernels, and per cent thin kernels. This reduction in quality was great enough that it could easily change a crop from "Malting Barley" to nonmalting or "feed" barley.

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